forest MANAGEMENT bulletin

SPECIES SUITABILITY AND pH OF SOILS IN SOUTHERN FORESTS

by
H. L. Williston
and
Russell LaFayette*

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U.S. Department of Agriculture, Forest Service, Southeastern Area, State and Private Forestry, 1720 Peachtree Road, N.W., Atlanta, Ga. 30309

IMPORTANCE OF pH IN FORESTRY

Soil pH is one of many properties governing the suitability of a site for planting or managing tree species. Situations that require some knowledge of the pH range throughout which a species makes good growth include:

The reforestation of strip mine spoil banks;
Shelterbelt plantings on agricultural soils;
Landscape planting in urban settings;
Landscaping on highway rights-of-way;
Erosion control planting;
The use of fertilizers to improve growth.

This bulletin will help foresters obtain a better working knowledge of soil pH-species-site relationships. Most foresters are familiar with the belief that pines like acid sites while hardwoods prefer alkaline soils. This belief is, of course, a gross over-simplification. Actually, most forest trees grow well over a wide range of pH values (see table 1), and the majority of hardwoods do best on slightly acid soils.

But just what is soil pH, and why is it significant in tree growth? Soil pH, also called soil reaction, is the logarithm of the reciprocal of the hydrogen ion (H+) concentration. Simply stated, the higher the hydrogen ion concentration (acidity) of a soil, the lower the pH value will be. A pH value of 7.0 is neutral, while values between 7.0 and 14.0 are basic or alkaline. Keep in mind that because these values are presented on a logarithmic scale, the differences between them are not simply one arithmetic unit, such as a rise from 6 to 7. The changes between whole units of pH are tenfold. That is, a value of 6.0 is ten times more acidic than 7.0, and 8.0 is one hundred times more alkaline than 6.0.

NUTRIENT UPTAKE AND TREE GROWTH

The soil pH influences nutrient uptake and tree growth in two general ways: through the direct effect of the hydrogen ion, and through the pH influence on nutrient availability and presence of toxic ions. In most soils, the latter effect is of greater importance. The majority of tree species tolerate wide ranges in hydrogen ion concentrations so long as a proper balance of other necessary growth elements is maintained. Soils with a pH of intermediate values (between 6.5 to 7.0) generally present the most satisfactory biological range. At these levels, most nutrients are readily available. At the same time, no elements are in oversupply. An excess of nutrients can harm trees in several ways. First, a nutrient excess can be toxic to the tree and kill or severely injure it. Second, an oversupply of one nutrient may interfere with the uptake of other essential elements. A good example of this problem of over-availability is evident at pH values below 5.0. Iron and manganese are needed only in very small amount, but in soils below pH 5.0 they are often soluble in sufficient quantities to be toxic to some plants. At the high end of the pH scale, the bicarbonate ion is sometimes present in sufficient quantities to interfere with the normal uptake of other needed ions and thus is detrimental to optimum growth.

Figure 1 illustrates the effect of pH on the availability of the essential nutrients and upon soil microorganisms. Several essential elements, including iron, manganese, and zinc, tend to become less available as the pH is raised from 5.0 to 7.5 or 8.0., while molybdenum increases in availability at the higher pH levels. Although phosphorous is not readily soluble in the soil, trees easily extract it from soils having a pH range between 6.0 and 7.0.

EFFECTS ON MICRO-ORGANISMS

Micro-organism activity is very important in the availability of various nutrients. Bacteria, including actinomycetes, function better at pH levels above 5.5 while fungi seems to flourish throughout the pH spectrum.

The work of micro-organisms is especially important in the conversion of nitrogen compounds into forms usable by plants. Mineralization (the changing of unavailable organic nitrogen to usable inorganic forms) is largely by microbial action. Therefore, pH values favoring fungal activity enhance the production of usable forms of inorganic nitrogen. Nitrification (the biological oxidation of ammonia nitrogen to nitrate nitrogen) takes place best between pH values of 5.5 to 10.0, with the optimum around 8.5. Nitrogen fixation (the process of converting inert elemental nitrogen to usable forms) is largely accomplished by a number of micro-organisms which require a pH greater than 5.5. It is evident that keeping the soil pH at levels that provide the best mix of nutrient availability and microbial activity is a necessity for successful tree growth.

*Mr. Williston is a pine specialist at the Southeastern Area's Field Office, Jackson, Miss. Mr. LaFayette was a hydrologist in the same office when this bulletin was prepared; he is now on the staff of the Chattahoochee-Oconee National Forests, Gainesville, Ga.

ACID SOILS

When soils are determined to be too acid, attempts are often made to raise the pH through liming. Soil, however, has a distinct resistance to changes in the pH of the soil solution. This resistance is termed "buffering." For many reasons, maintaining a favorable pH through liming is important. But probably the greatest direct benefit of liming acid soils is the reduction of activity or solubility of aluminum and manganese. Both of these ions in anything over very low concentrations are toxic to most plants.

Soil from mining operations or channel alteration may have pH values from less than 3.0 to as much as 8.3. No vegetation can be expected to survive and grow below a pH of 3.5 without intensive spoil treatment to raise the pH to tolerable levels. The Soil Conservation Service in Kentucky has tabulated the more important species for stabilizing spoil materials according to pH classes (table 2). Test the pH of the spoil after final grading and before planting to help select the most suitable species. However, the pH may increase or decrease over a period of time because of climatic and vegetation factors, and it should be checked and altered if necessary. Special concern is needed where sulfur is present in the spoil material because the sulfur can react with air and water to form sulfuric acid. This acid can reduce pH values below 2.0 where initial values were above 5.0. If the spoil is to be reclaimed for farming uses such as hay or pasture, or seeded to

Table 1. –Soil pH range for southern tree species

Common name	Scientific name	Range in pH	Common name	Scientific name	Range in pH
Alder, European black	*Alnus glutinosa*	4.0-7.0	Oak, laurel	*Q. laurifolia*	3.6-5.6
Ash, green	*Fraxinus pennsylvanica*	3.6-7.5	Oak, live	*Q. virginiana*	6.0-7.5
Ash, white	*Fraxinus americana*	4.6-7.5	Oak, northern red	*Q. rubra*	4.5-6.0
Baldcypress	*Taxodium distichum*	4.6-7.5	Oak, Nuttall	*Q. nuttallii*	3.6-6.8
Basswood, American	*Tilia americana*	4.6-8.0	Oak, overcup	*Q. lyrata*	3.6-5.5
Beech, American	*Fagus grandifolia*	6.0-7.0	Oak, pin	*Q. palustris*	6.0-7.0
Birch, black	*Betula lenta*	5.0-6.0	Oak, post	*Q. stellata*	5.0-6.0
Birch, river	*B. nigra*	4.5-6.0	Oak, scarlet	*Q. coccinea*	6.0-7.0
Birch, yellow	*B. alleghaniensis*	5.0-7.0	Oak, shumard	*Q. shumardii*	4.4-6.2
Blackgum	*Nyssa sylvatica*	4.6-7.0	Oak, southern red	*Q. falcata* var. falcata	5.0-6.0
Buckeye	*Aesculus* species	6.0-8.0	Oak, swamp chestnut	*Q. michauxii*	3.6-6.2
Catalpa	*Catalpa* species	6.0-8.0	Oak, swamp white	*Q. bicolor*	6.0-8.0
Cedar, Atlantic white	*Chamaecyparis thyoides*	3.5-5.5	Oak, water	*Q. nigra*	3.6-6.3
Cherry, black	*Prunus serotina*	4.6-6.2	Oak, white	*Q. alba*	4.5-6.2
Cherry, fire	*P. pensylvanica*	5.0-6.0	Oak, willow	*Q. phellos*	3.6-6.3
Chestnut, American	*Castanea dentata*	5.0-6.0	Paulownia	*Paulownia tomentosa*	6.0-8.0
Chinkapin	*C. pumila*	5.0-6.0	Pecan	*Carya illinoensis*	4.8-7.5
Cottonwood, eastern	*Populus deltoides*	3.6-7.5	Persimmon	*Diospyros virginiana*	4.4-7.0
Dogwood	*Cornus* species	6.0-8.0	Pine, loblolly	*Pinus taeda*	4.5-6.0
Elm	*Ulmus* species	5.2-8.0	Pine, longleaf	*P. palustris*	4.5-6.0
Eucalyptus	*Eucalyptus* species	6.0-8.0	Pine, pitch	*P. rigida*	3.5-6.0
Hackberry	*Celtis occidentalis*	5.0-7.5	Pine, scotch	*P. sylvestris*	4.5-6.0
Hemlock, eastern	*Tsuga canadensis*	5.0-6.0	Pine, shortleaf	*P. echinata*	4.5-6.0
Hickory	*Carya* species	4.5-5.5	Pine, slash	*P. elliottii*	4.5-6.0
Holly, American	*Ilex opaca*	5.0-6.0	Pine, Virginia	*P. virginiana*	4.6-7.9
Honeylocust	*Gleditsia triacanthos*	6.0-8.0	Pine, eastern white	*P. strobus*	4.5-6.0
Hophornbeam, eastern	*Ostrya virginiana*	6.0-7.0	Redcedar, eastern	*Juniperus virginiana*	6.0-7.5
Kentucky coffeetree	*Cymnocladus dioicus*	6.0-8.0	Redbud, eastern	*Cercis canadensis*	6.0-8.0
Locust, black	*Robinia pseudoacacia*	4.5-7.5	Sassafrass	*Sassafras albidum*	4.7-7.0
Magnolia, southern	*Magnolia grandiflora*	5.0-6.0	Sourwood	*Oxydendrum arboreum*	4.0-8.0
Maple, red	*Acer rubrum*	4.4-7.5	Spruce, red	*Picea rubens*	4.0-5.5
Mulberry	*Morus* species	6.0-8.0	Sumac, shining	*Rhus copalina*	4.2-7.0
Oak, bear	*Quercus ilicifolia*	4.0-5.0	Sweet bay	*Magnolia virginiana*	4.0-5.0
Oak, black	*Q. velutina*	5.0-5.4	Sweetgum	*Liquidambar styraciflua*	3.6-7.5
Oak, blackjack	*Q. marilandica*	5.0-6.0	Sycamore, American	*Platanus occidentalis*	4.4-7.5
Oak, bur	*Q. macrocarpa*	6.0-6.3	Tupelo, water	*Nyssa aquatica*	3.6-5.6
Oak, cherrybark	*Q. falcata* var. pagodaefolia	4.5-6.2	Walnut, black	*Juglans nigra*	5.0-7.5
			Willow, black	*Salix nigra*	4.6-7.5
Oak, chestnut	*Q. prinus*	5.0-7.0	Yellow-poplar	*Liriodendron tulipifera*	4.5-7.0

similar vegetation prior to the establishment of tree species, the pH should be maintained at approximately 5.5 for adequate survival and growth.

ALKALINE SOILS

Some agricultural lands where shelterbelts are needed may be too alkaline for good growth of pines. A simple test is a drop of hydrochloric acid (HCl) on the soil. Fizzing will indicate the presence of excess carbonates or bicarbonates, a sure sign of a poor pine site. On those Southern soils that won't support loblolly or slash pine, acceptable shelterbelt species are Arizona cypress, blackgum, black locust, cottonwood, European alder, honeylocust, persimmon and redcedar.

Where there has been severe soil disturbance by erosion or mechanical means such as bulldozing, land leveling, or road construction, a soil test is needed before trees are planted. Removal of an acid topsoil may leave an alkaline subsoil. In some situations, loblolly wouldn't survive as a yard tree, but red maple, cypress, magnolia, and pecan grew well. In other situations, loblolly failed on a road cut,

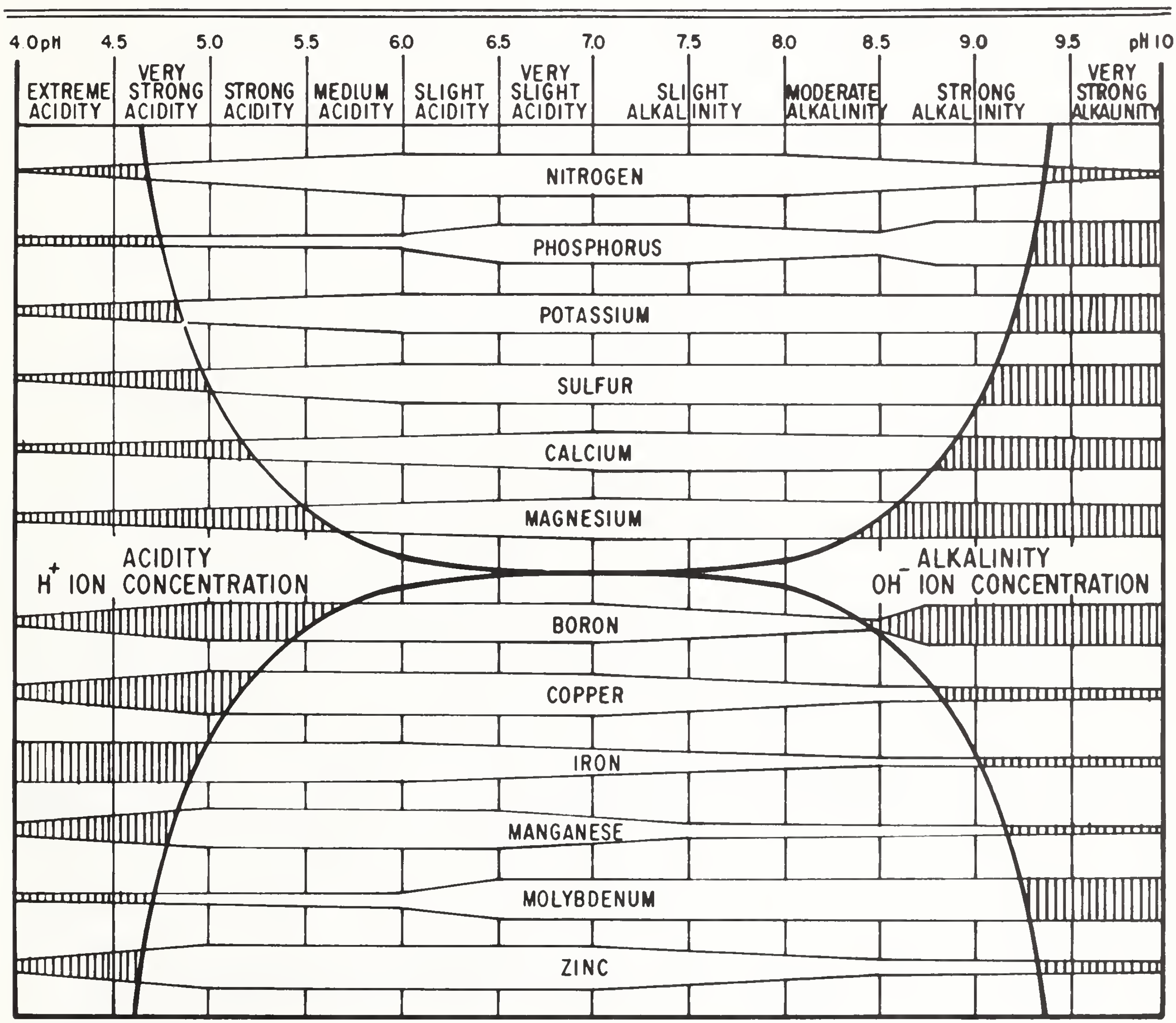

Figure 1.–Effect of soil pH and associated factors on the availability of plant nutrient elements. The width of the band for each element indicates the relative favorableness of this pH value and associated factors to the presence of the elements in readily available forms (the wider the band the more favorable the influence). It does not necessarily indicate the actual amount present since this is influenced by other factors. (Reproduced from *Changing Patterns in Fertilizer Use,* p. 152, 1968, by permission of the Soil Science Society of America.)

Table 2. –Species suitable for planting on spoil banks in Kentucky.

pH 3.6 to 5.5	pH 5.6 to 7.3	pH above 7.3
Alder, European black	Alder, European black	Ash, green
Ash, green	Ash, green	Cottonwood, eastern
Ash, white	Ash, white	Locust, black
Birch, river	Birch, river	Poplar, hybrid
Chestnut, Chinese	Chestnut, Chinese	Redcedar, eastern
Locust, black	Cottonwood, eastern	Sycamore, American
Oak, northern red	Locust, black	Walnut, black
Pine, loblolly	Oak, northern red	
Pine, pitch	Pine, loblolly	
Pine, Scotch	Pine, pitch	
Pine, shortleaf	Pine, Scotch	
Pine, Virginia	Pine, Virginia	
Pine, eastern white	Pine,eastern white	
Sweetgum	Poplar, hybrid	
Sycamore, American	Redcedar, eastern	
	Sweetgum	
	Sycamore, American	
	Walnut, black	
	Yellow-poplar	

but redcedar did well. When you sample the soil before planting trees, study both the top and subsoil, because pH values for the A and B horizon may differ greatly. Tree roots passing through a well-suited topsoil may encounter an unsuitable pH in the subsoil, resulting in poor growth or mortality. It is also best to test for pH when the soil is moist: not too wet or too dry. Waterlogged soils consistently test between 6.5 and 7.0, while the same soil will test at 4.0 to 4.5 when very dry.

EFFECT ON FERTILIZATION

Of great importance is the effect soil pH has on a forest fertilization program. Fertilization of young pine stands with nitrogen now appears to be effective in the Piedmont and upper Coastal Plain, while the addition of phosphorus is most important in the lower Coastal Plain.

Phosphorus (P) is most easily utilized by pine when the pH is 5.8 to 6.0. In the long term, the availability of P is controlled largely by the amount of iron in the soil, and by aluminum concentration – whereby P is precipitated into slowly soluble forms (a reaction influenced by pH level). Incidentally, burning of weeds and other unwanted vegetation, as well as forest fires, increases available P and may extend the effectiveness of phosphorus fertilization.

While soil pH is critical for use of nitrogen fertilizers on some crops, this is not the case with pines. Nitrogen fertilization at the time of planting increases the nutrient component of grasses, weeds and shrubs – and the trees benefit through the cycling process when the understory vegetation is shaded out. Fertilization in well-stocked pine pulpwood stands affects stand development by inducing mortality of the suppressed trees and by stimulating the diameter growth of the larger trees.

Note: climate, soil type, soil properties etc., can produce inconsistencies in such a compilation. Broadfoot published the most complete information. We used his pH determination for soils on which he specified that a given species should be favored in management and could be expected to make either the best growth or good growth. On heavy clay soils, we used his pH values to a depth of 2 feet (61 cm); on the better soils to a depth of 4 feet (122 cm). For the more shallow-rooted pine, pH to a depth of 2 feet (61 cm) should be satisfactory.

SUGGESTED READING

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